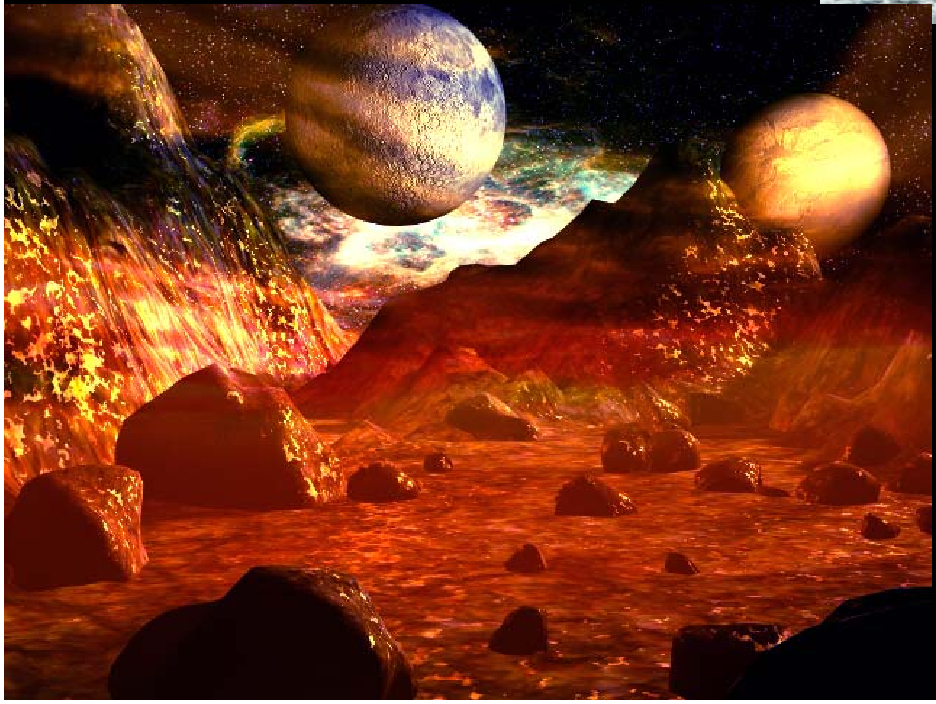
LIFE DETECTION AND CHARACTERIZATION OF SUBSURFACE ICE AND BRINE IN THE MCMURDO DRY VALLEYS USING AN ULTRASONIC GOPHER.



Science

Peter Doran and Fabien Kenig,
University of Illinois at Chicago
Chris Fritsen and Alison Murray,
Desert Research Institute
Chris McKay,
NASA Ames

Engineering

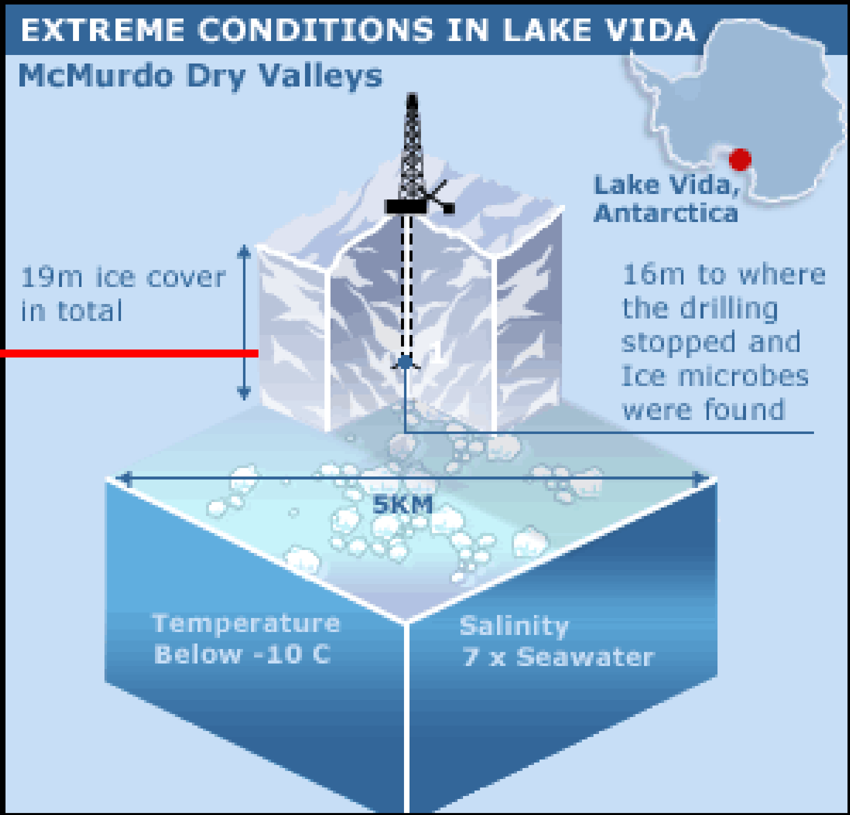
Yosi Bar-Cohen and team,
Jet Propulsion Lab

Where we're going

- Goals of our ASTEP project
- Quick review of typical perennially ice-covered lacustrine environments in the dry valleys
- Ice sealed lakes (e.g. Lake Vida)
- Ice gopher design and progress
- Preparations for field season

Samples and measurements previously acquired

Unexplored



- Our goal is to use a lightweight, low power ultrasonic “ice gopher” to core an ~20 m sediment laden lake ice cover and to sample ice, brine and sediment from beneath

- Sampling must be done “aseptically” and maintain lake pressure (Antarctic environmental requirement)

-Analogous environments include ice-rich ground and potential subsurface fluids on Mars. Europa lander.

The Future at Lake Vida

NASA Astrobiology Science and Technology for Exploring Planets (ASTEP)

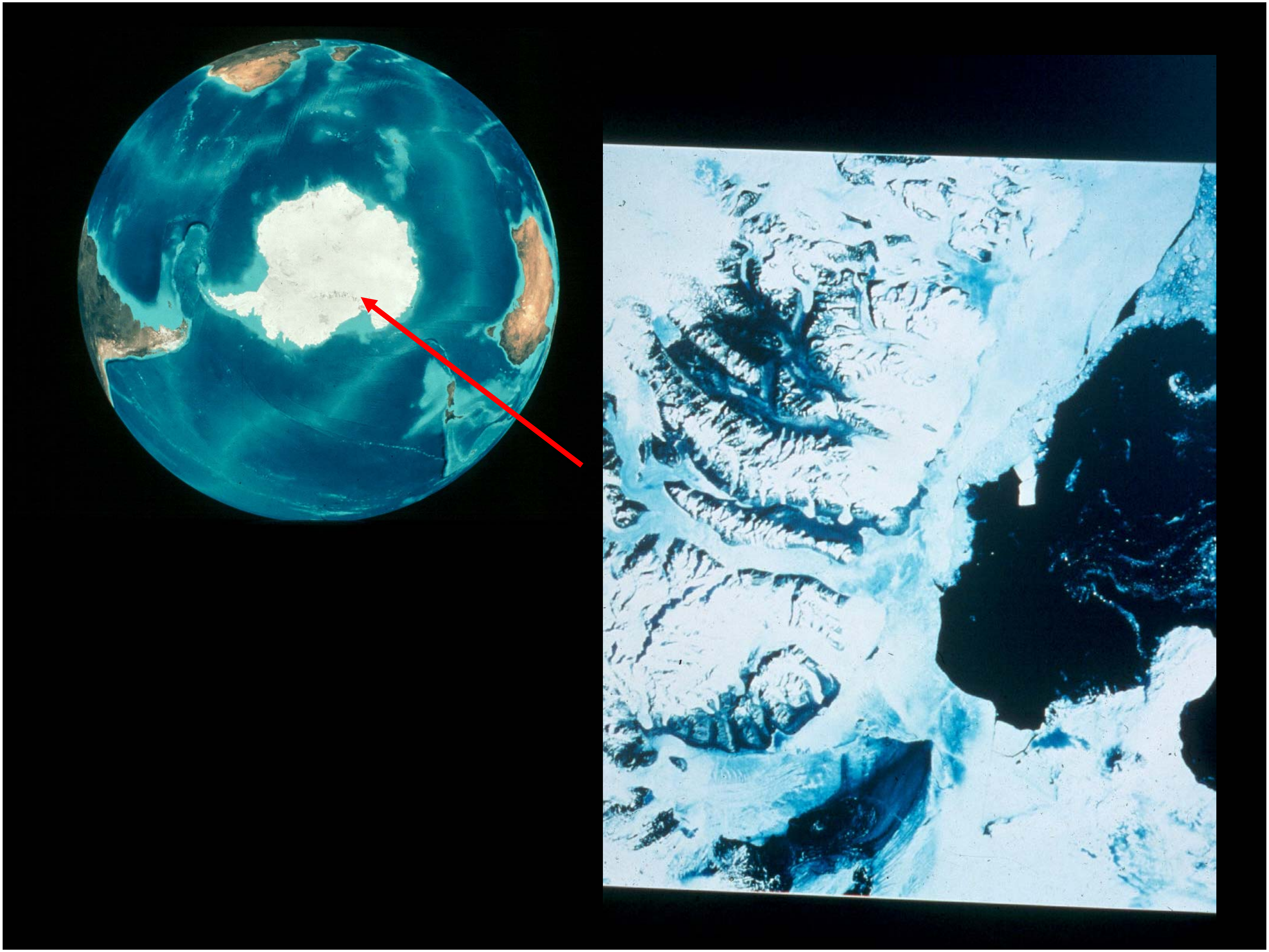
Ultra Sonic Gopher for Sampling Planetary Ice-covered Environments (Ice Gopher)

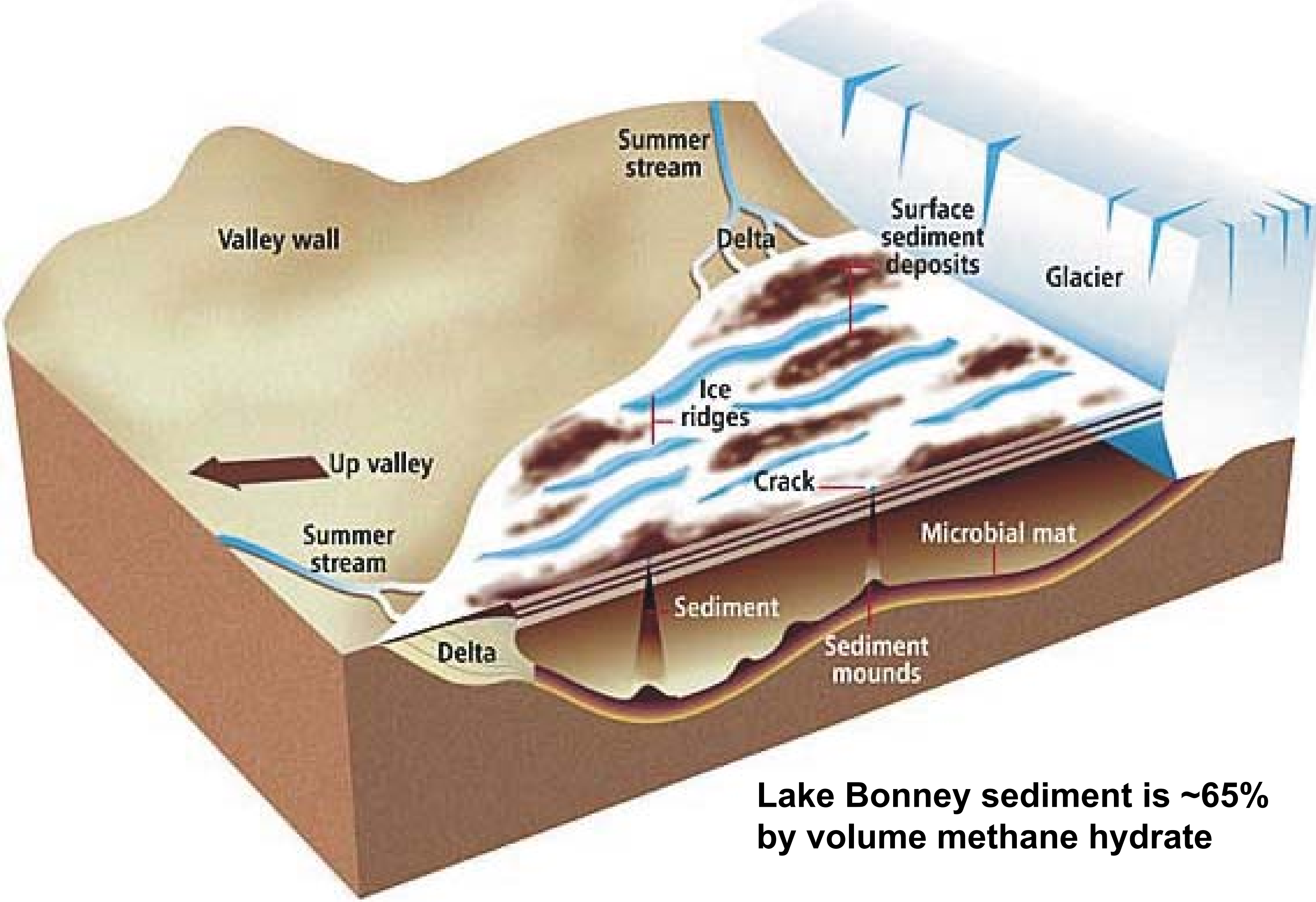
In the field November 2004: Brine or Bust!

Two general hypotheses will be tested:

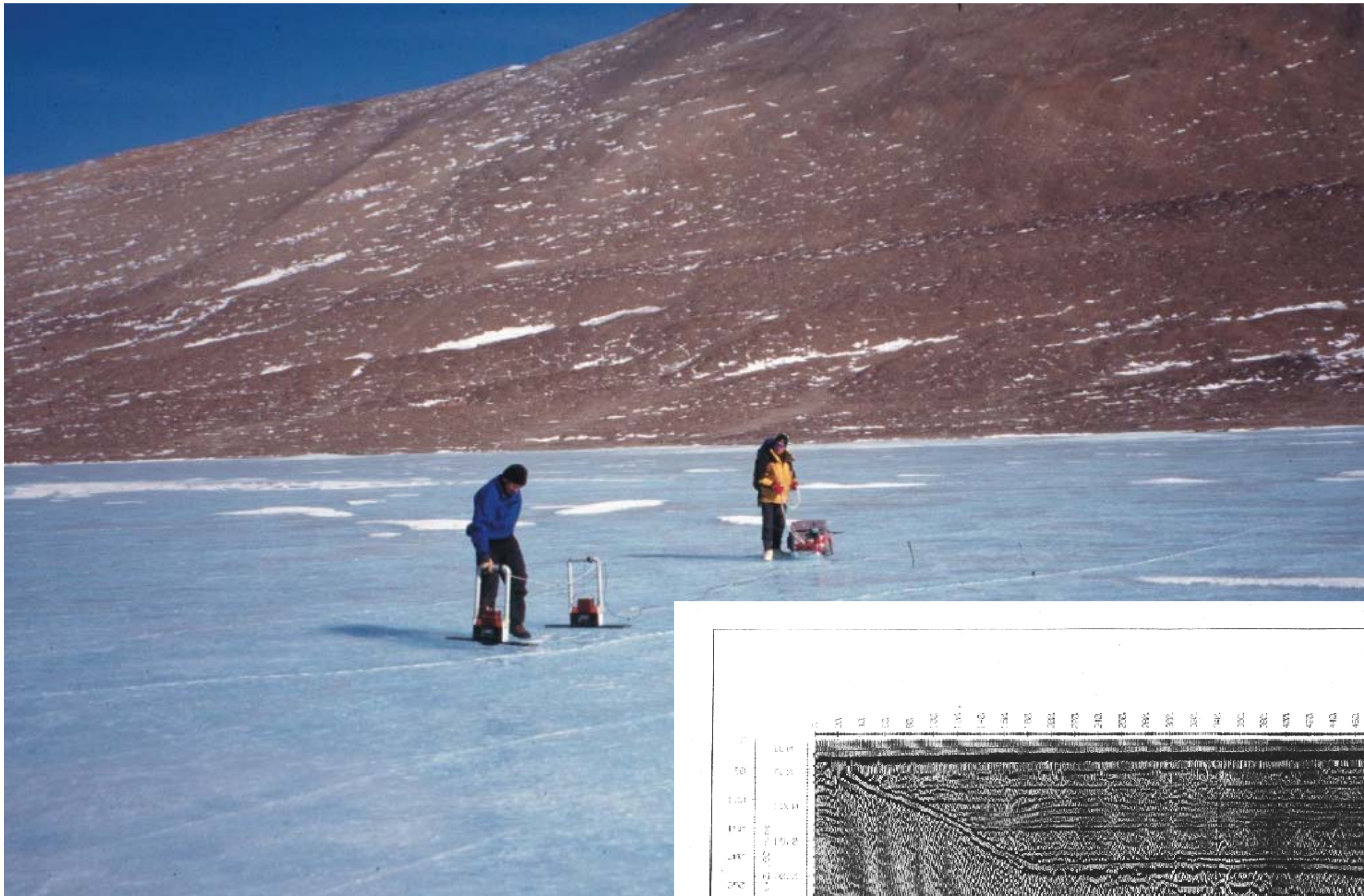
H1: Microbial communities within the brine (including brine pockets in the deep ice) and benthic sediments are currently viable, active and affect the present-day geochemistry of the lake.

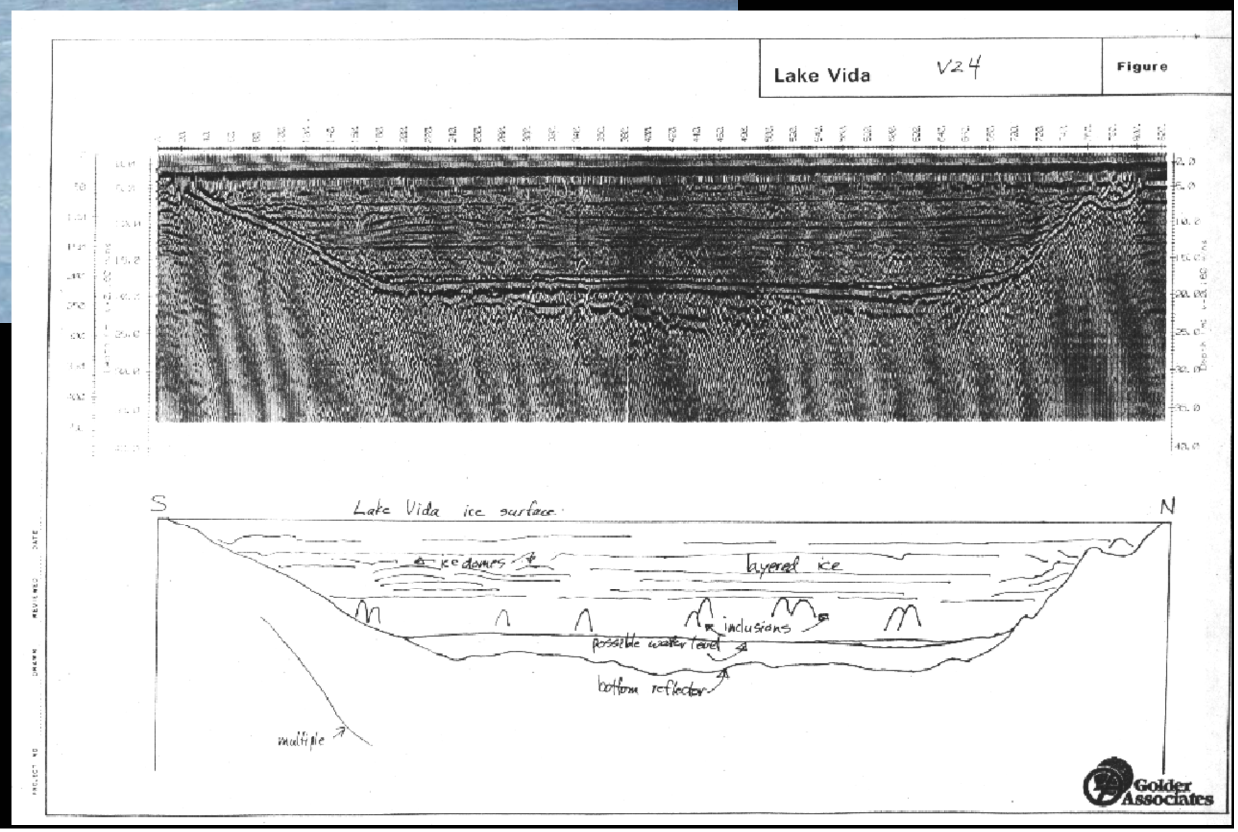
H2: Ice, brine and benthos of Lake Vida contain geochemical signatures of past microbiological activity.



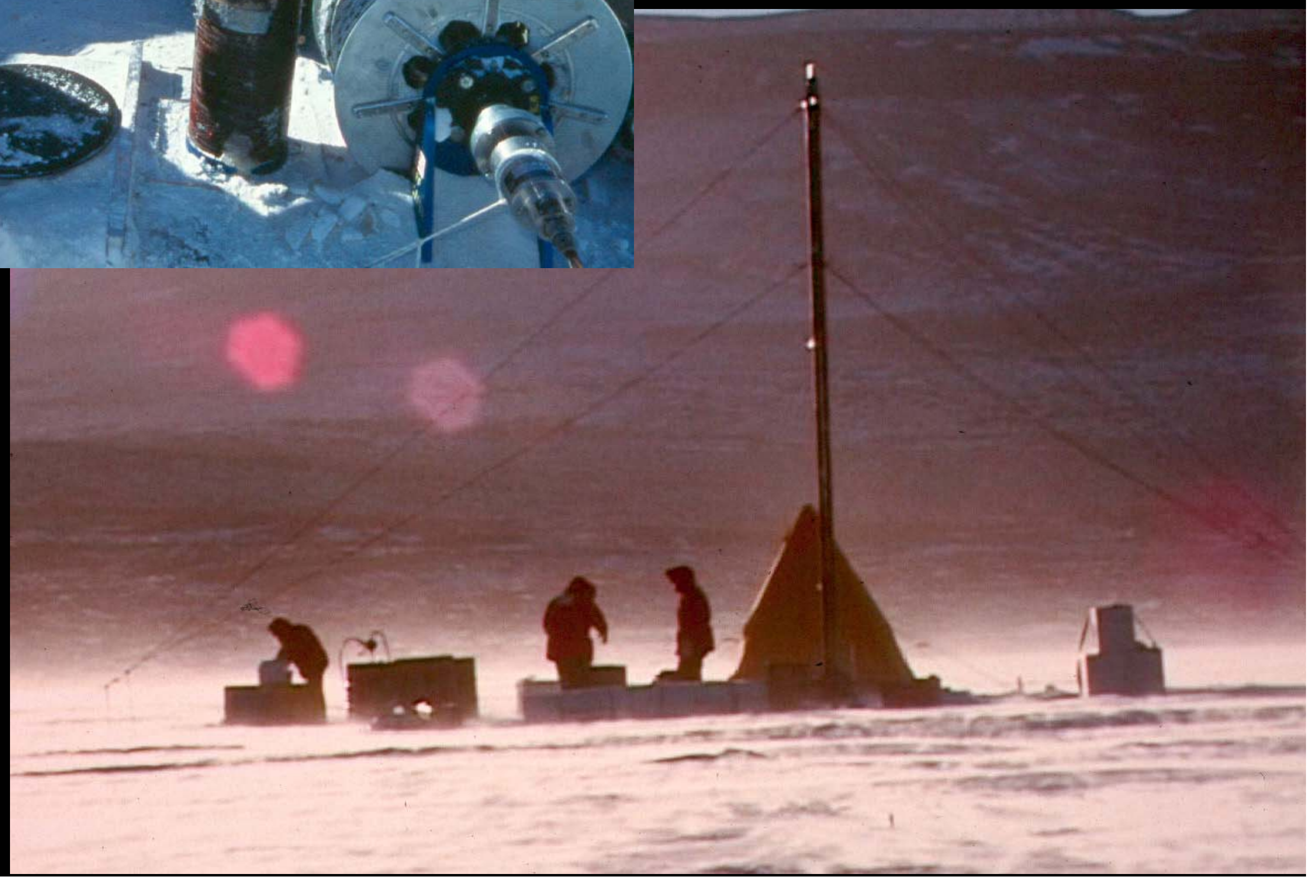


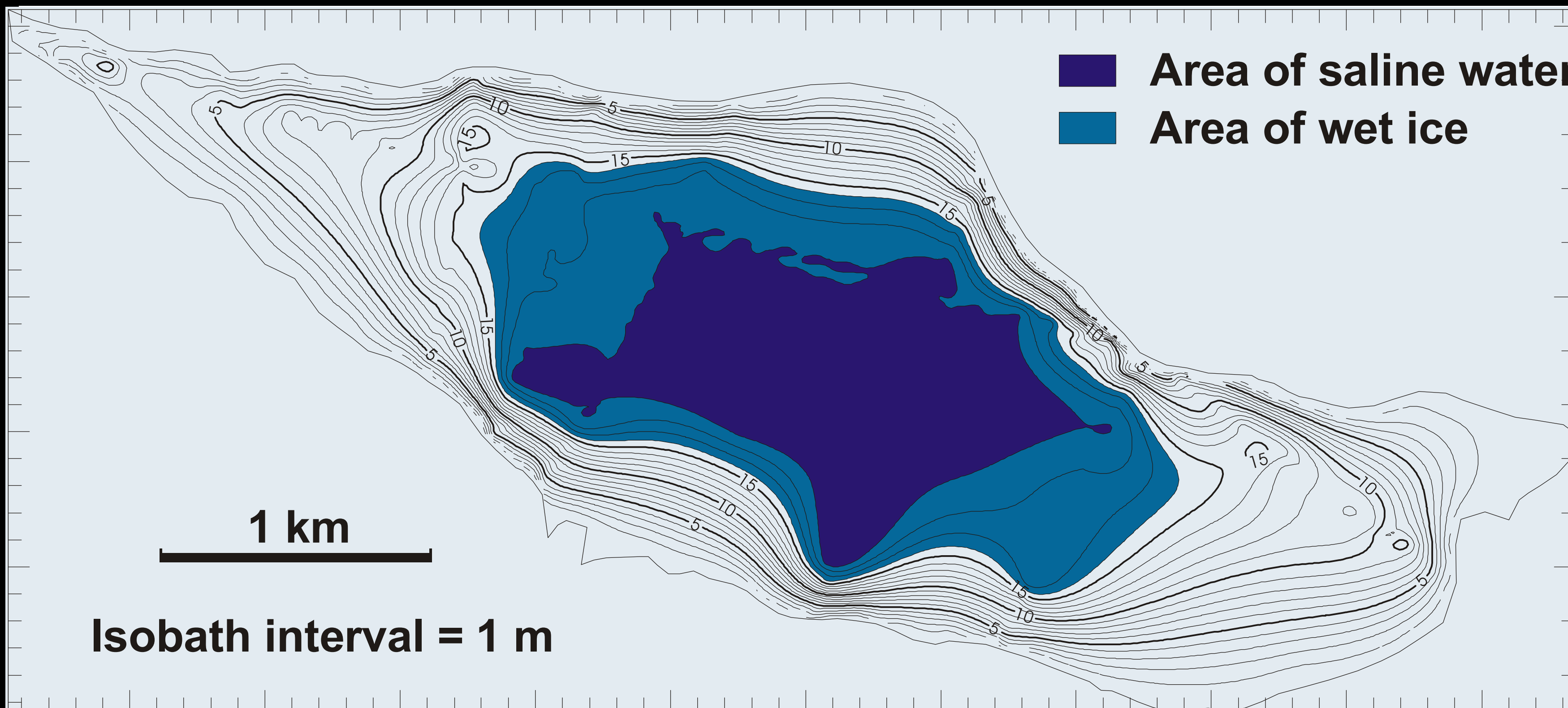
Lake Bonney sediment is ~65% by volume methane hydrate



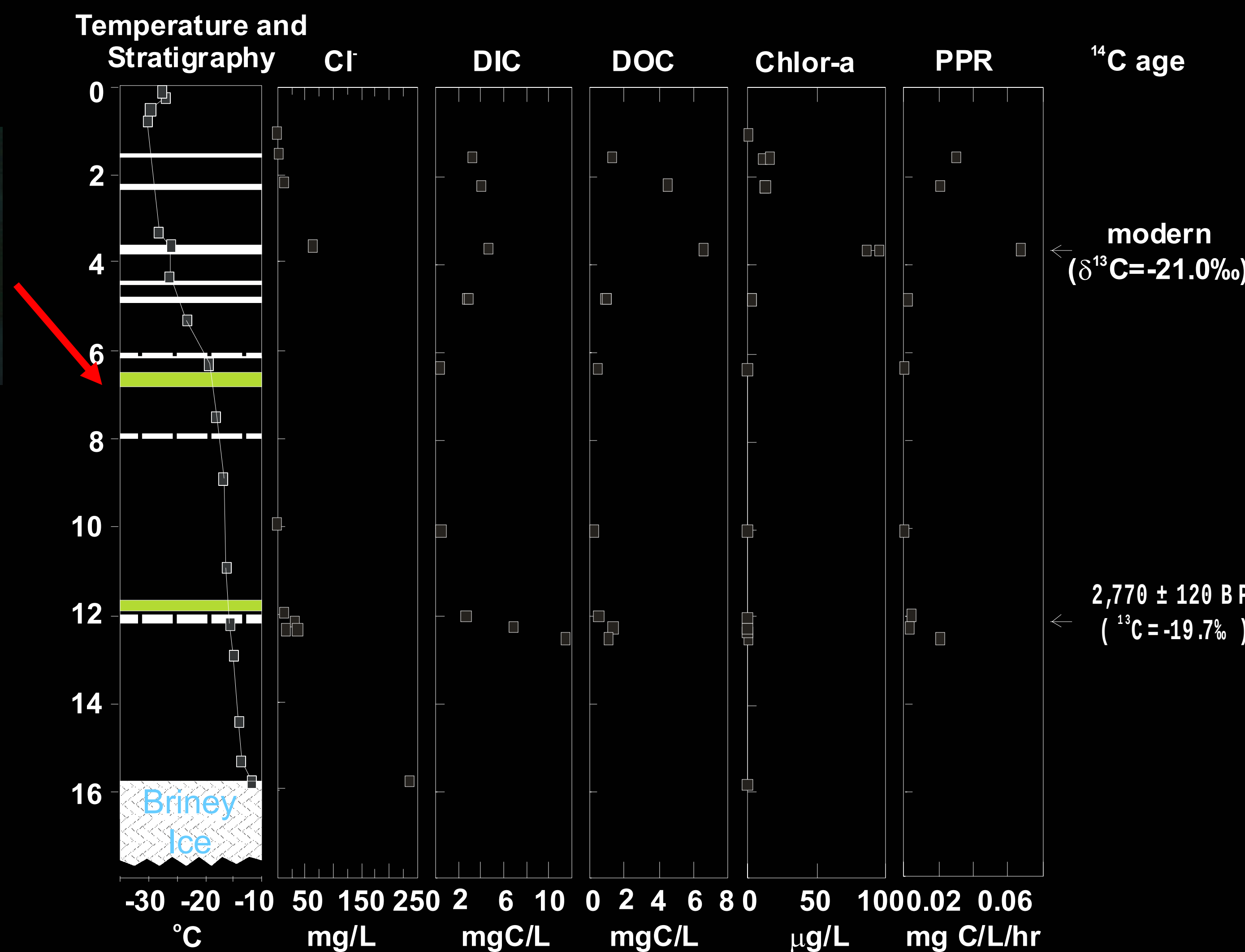


Lake Vida V24
Figure
S
N
Lake Vida ice surface
ice domes
layered ice
inclusions
possible water level
bottom reflector
multiple
Golder Associates

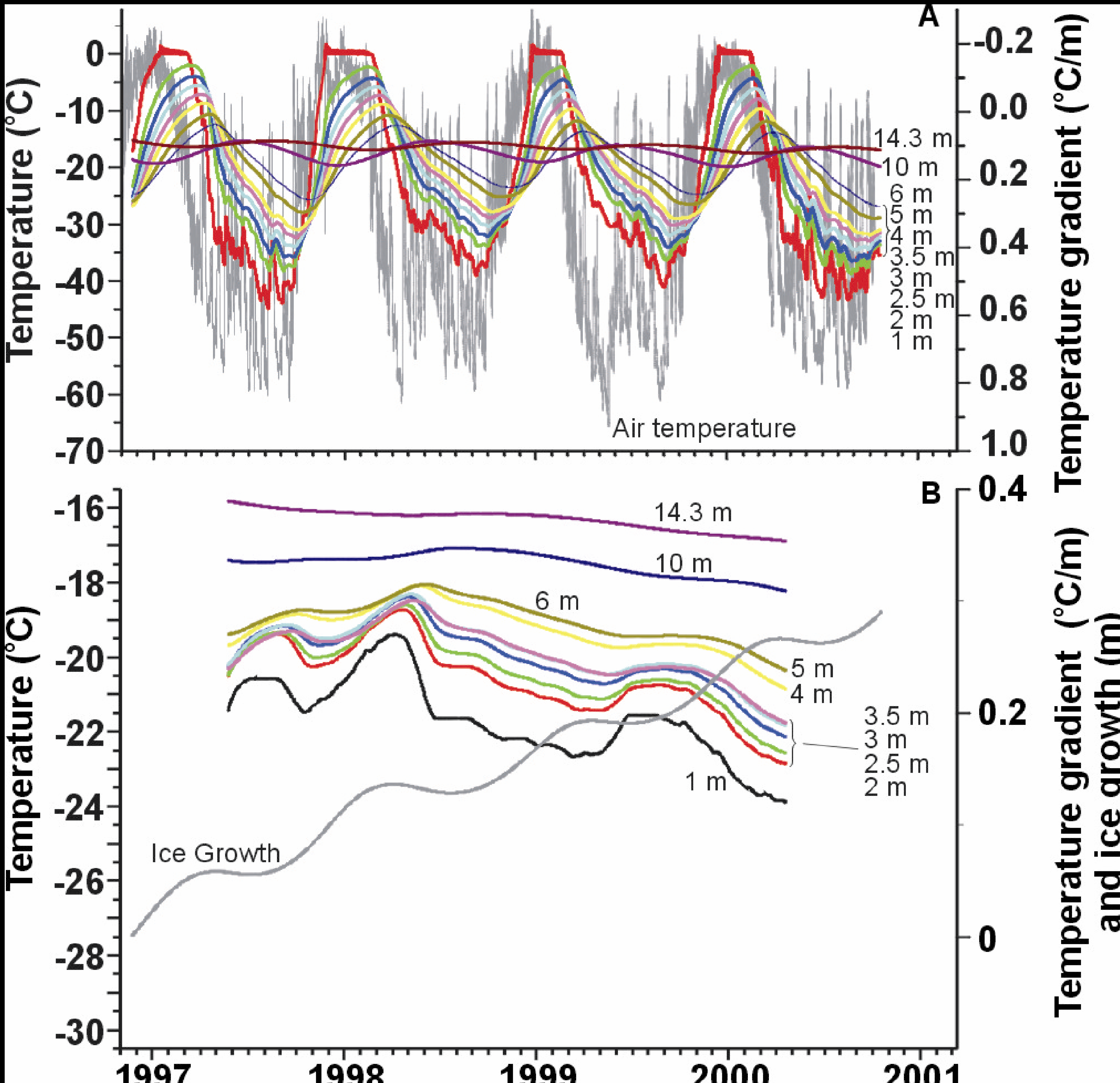




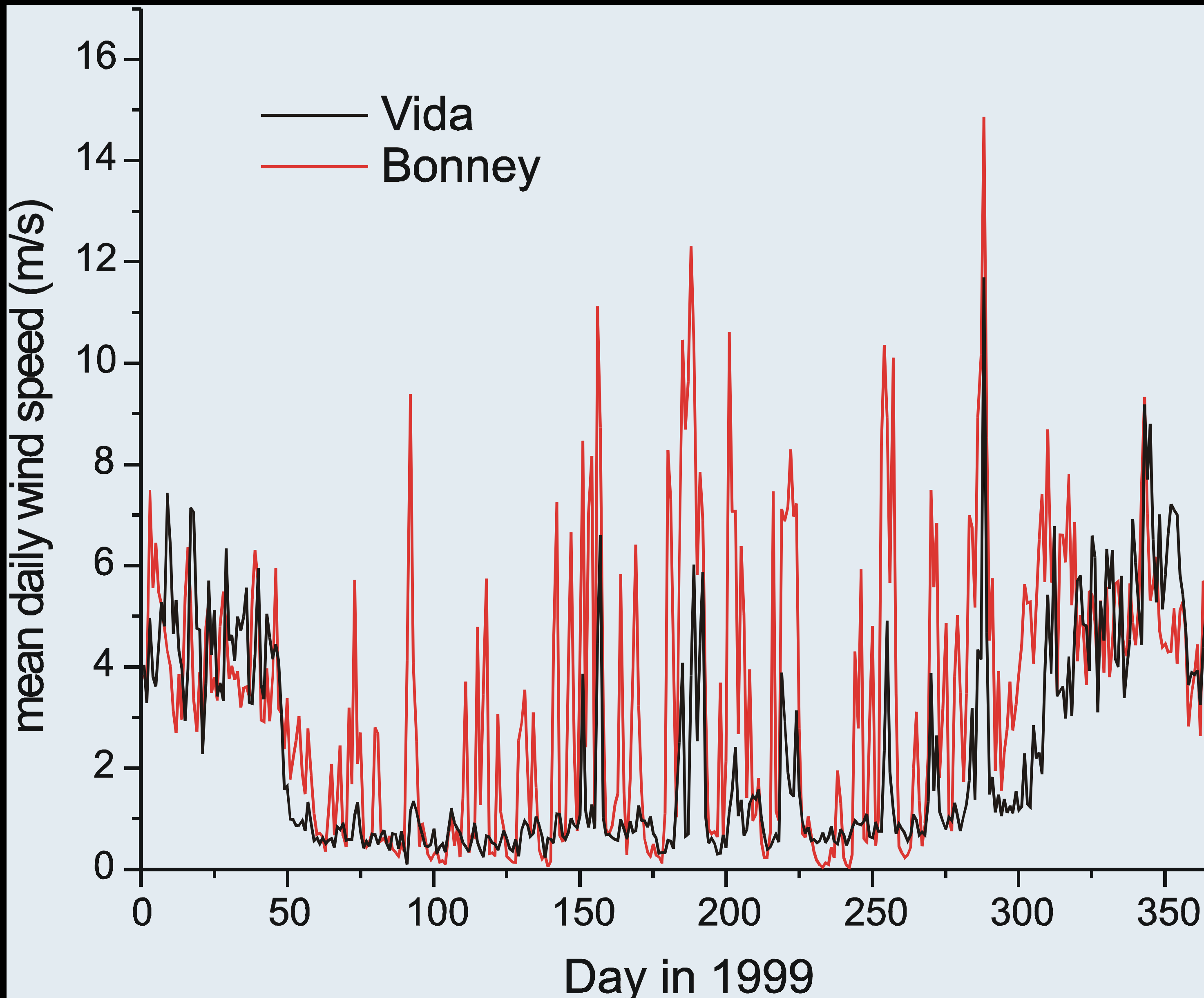
Area of saline water
Area of wet ice
1 km
Isobath interval = 1 m

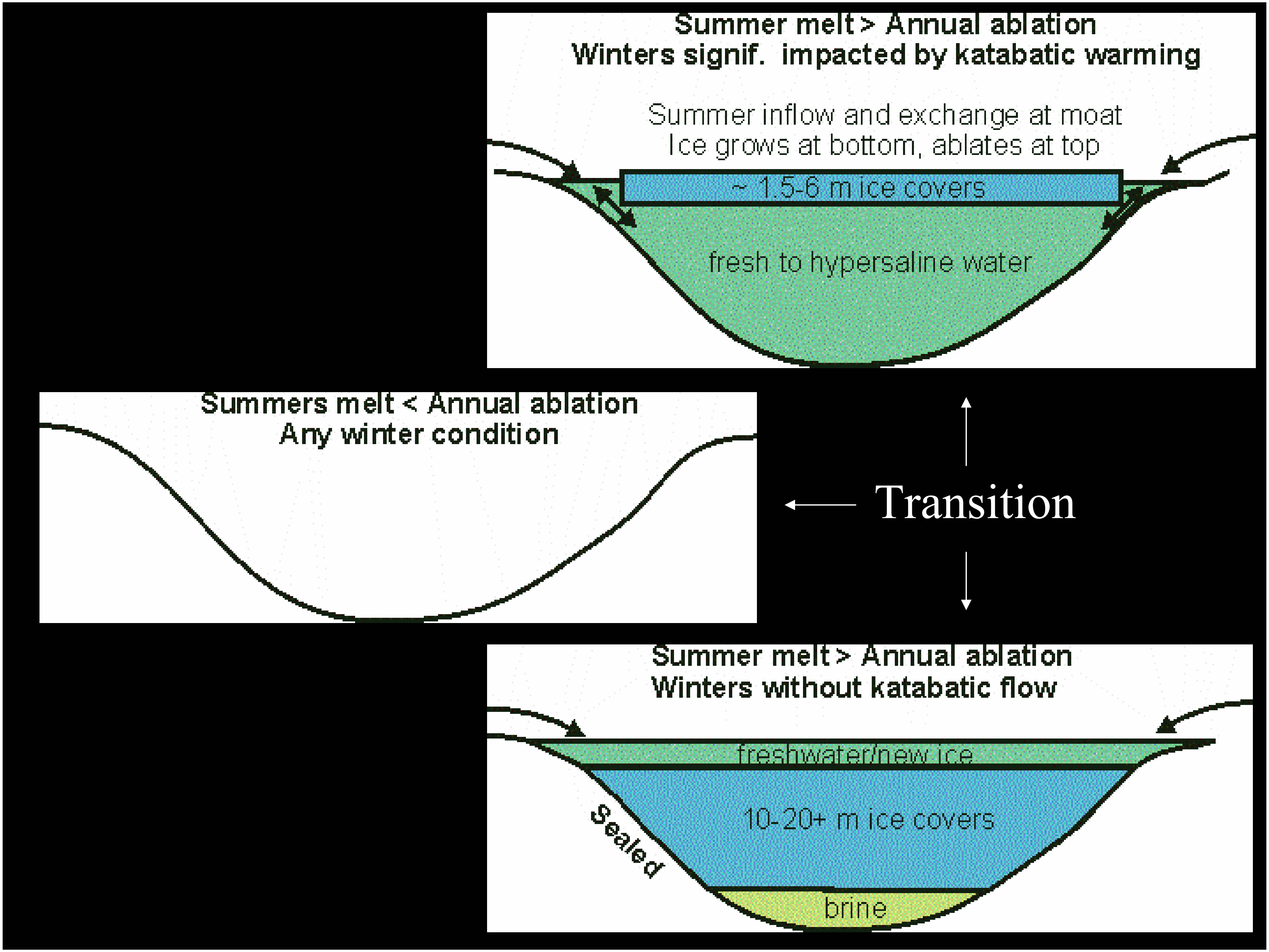


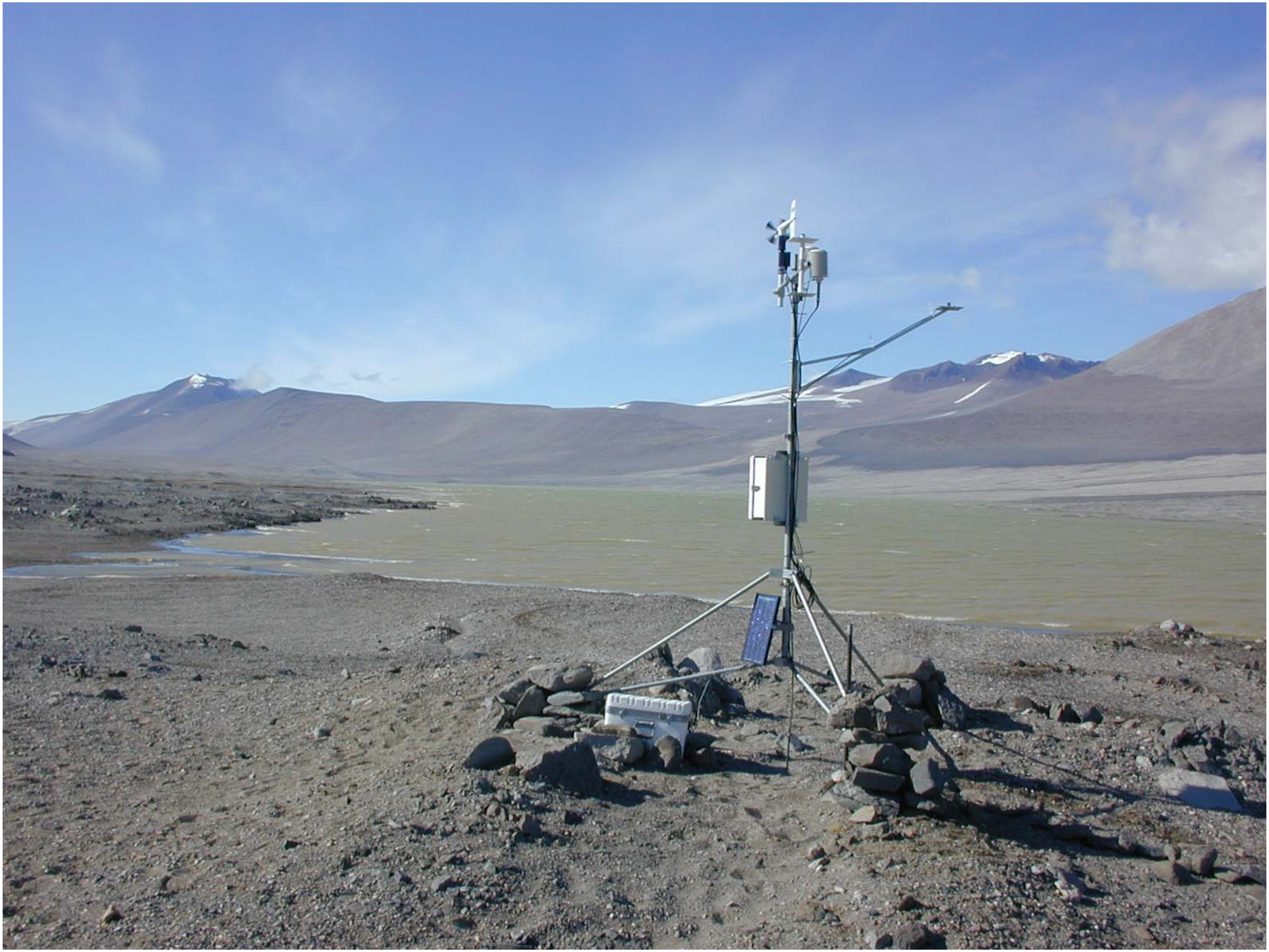
NaCl brine. 7 times seawater (245 ppt)



A
B
Temperature (°C)
Temperature gradient (°C/m)
Temperature gradient (°C/m) and ice growth (m)
0
-10
-20
-30
-40
-50
-60
-70
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
14.3 m
10 m
6 m
5 m
4 m
3.5 m
3 m
2.5 m
2 m
1 m
Air temperature
-16
-18
-20
-22
-24
-26
-28
-30
0.4
0.2
0
Ice Growth
1997
1998
1999
2000
2001


Vida
Bonney
mean daily wind speed (m/s)
0
2
4
6
8
10
12
14
16
0
50
100
150
200
250
300
350
Day in 1999


Summer melt > Annual ablation
Winters signif. impacted by katabatic warming
Summer inflow and exchange at moat
Ice grows at bottom, ablates at top
~ 1.5-6 m ice covers
fresh to hypersaline water
Summers melt < Annual ablation
Any winter condition
Transition
Summer melt > Annual ablation
Winters without katabatic flow
freshwater/new ice
10-20+ m ice covers
Sealed
brine



Culturability of Vida Ice Microbes (6.7 to 6.86 meters)

Media Type	Total Cell Count (cells/ml)	Culturable Cell Count (cells/ml)	Percent of Culturable Cells
R2A Agar	1.27E+06	1.93E+03	0.15%
10% R2A Agar	1.27E+06	1.40E+03	0.11%
NDBG11 Agar	1.27E+06	1.50E+01	0.0012%
BG11 Agar	1.27E+06	2.50E+01	0.0020%
Halophilic Agar	1.27E+06	0	0%
R2A Agar with Salts	1.27E+06	0	0%
10% R2A Agar with Salts	1.27E+06	0	0%

Lake Vida Microbial Community Composition:

DNA Extraction Efficiencies

Depth in Ice Cover (m)	Cell Count (cells/ml)	(fg DNA/ cell filtered)
4.67-4.82	1.98E+06	5.13
6.70-6.86	1.27E+06	2.91
11.6-11.8	4.53E+05	5.77
14.47-14.65	1.06E+05	9.39
15.5-15.85	1.16E+05	3.22

Lake Vida Microbial Community Composition:

Preliminary PCR Screening

Depth in Ice Cover (m)	Presence of Bacteria	Presence of Archaea*	Presence of Eukarya
4.67-4.82	+	-	+
6.70-6.86	+	-	+
11.6-11.8	+	-	+
14.47-14.65	+	-	+
15.5-15.85	+	-	-

PCR screening of archaea and eukarya will be used to determine the presence or absence of archaea and eukarya. Extracted DNA will be amplified with archaea and eukaryotic specific primers and visualized on an 1% agarose gel.

PCR Screening for Bacteria, Eukarya and Archaea

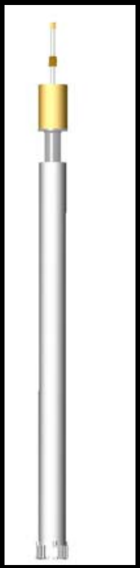
Archaea Primers: 20F and 958R

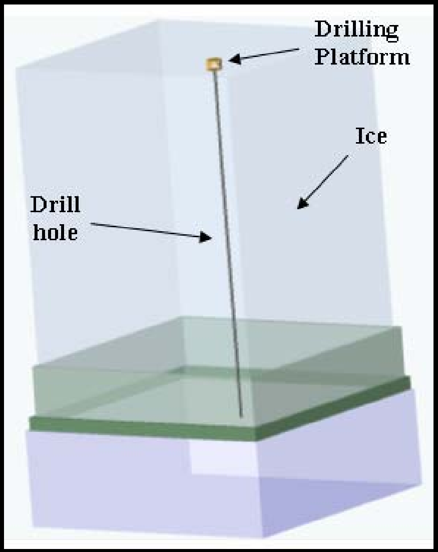
Eukarya Primers: Euk1A and 1200R

ASTEP Program, PI: Peter Doran, UIC

Subsurface Ice and Brine Sampling: Life Detection and Characterization in the McMurdo Dry Valleys Using an Ultrasonic/Sonic Gopher

View of the new Gopher





JPL responsibility

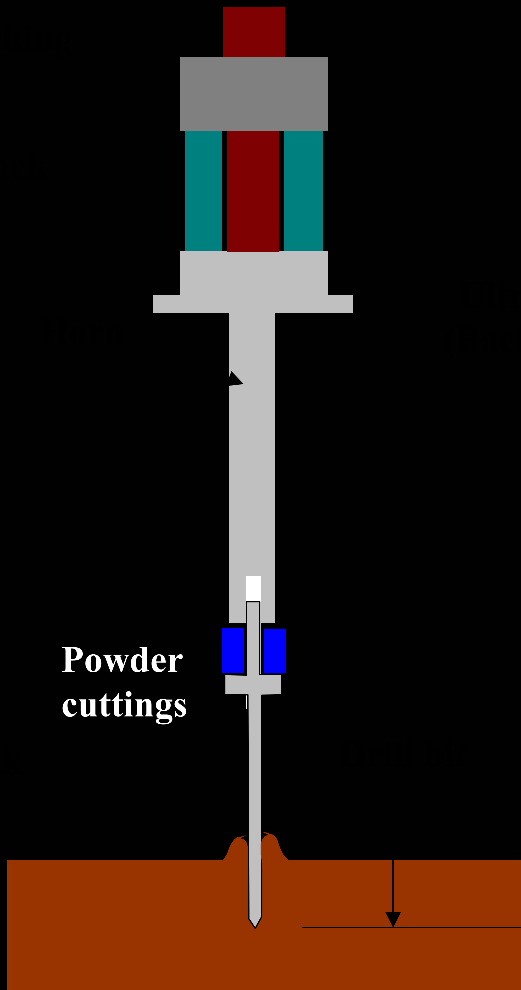
PI: **Yoseph Bar-Cohen**

Co-I: **Stewart Sherrit, Xiaoqi Bao and Zensheu Chang**

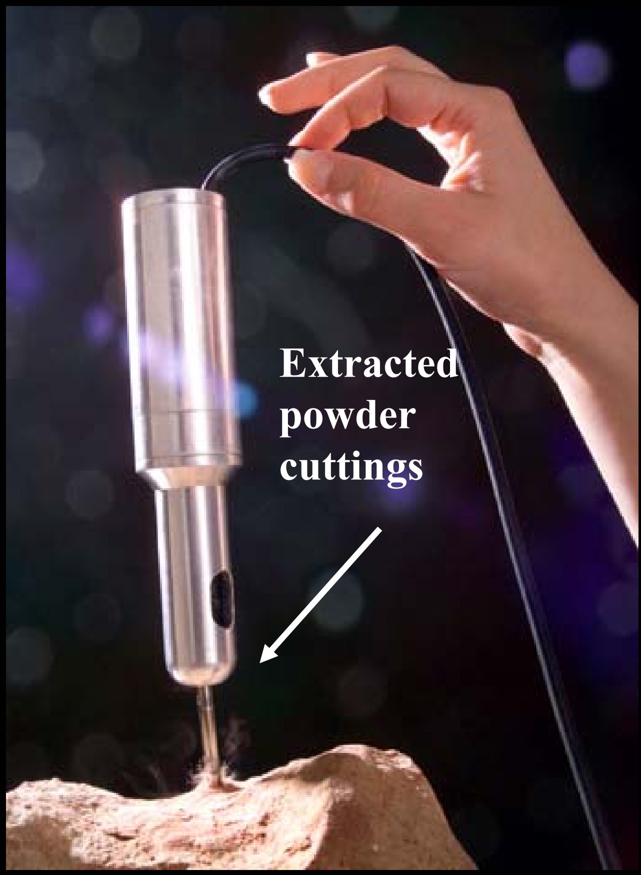
Industrial partner: **Cybersonics**

Jan 13, 2004

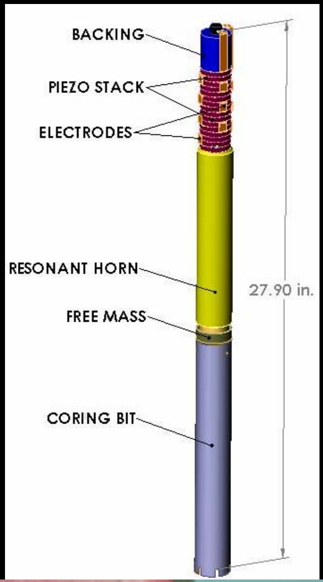
Ultrasonic/Sonic Driller/Corer (USDC)



2000 R&D 100 award



Ultrasonic/Sonic Gopher



- The technology is based on the ultrasonic/sonic driller/corer (USDC).
- Vibrations from a piezoceramic stack are amplified by an inverted horn impacting a free-mass to hammer the coring bit at low frequencies.
- The coring bit has a diameter larger than the actuator located behind it.
- The gopher is designed to be downloaded and uploaded in the drilled borehole bringing cores to the surface.

Gopher development

- Two key components are believed to be critical for the optimization of the gopher: The bit and its cutting edge as well as the actuator and its driver.
- Two prototypes of 5-cm diameter U/S gophers were produced in an effort to optimize the design and reach the goal of 20-m deep coring thru -20^{o}C ice.
- The prototypes were produced with two coring bit lengths of 50-cm (at JPL) and 30-cm (at Cybersonics) and the bit was made of three test materials: aluminum, titanium and stainless steel.
  - A drive electronics was made with selectable frequency range 5 -25 kHz , having adjustable duty cycle and power and with a maximum output power of 500 Watts to the gopher.
  - Three horn configurations were studied: conventional (step down in diameter from the piezoelectric stack), solid horn (same diameter as the stack) and a dog bone shape
  - Free mass in various dimensions were made for the optimization of the actuation mechanism.
  - Two methods of core cutting are studied: wire cutter and ice scream scooping.

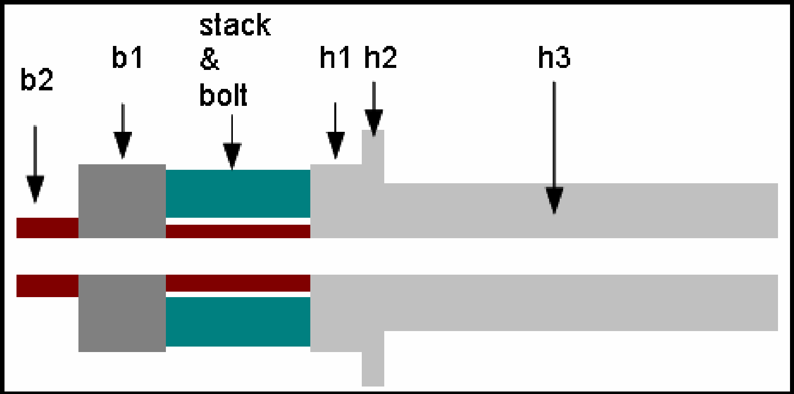
Optimization Setups

- Test setups were constructed to test the various elements of the Gophers.

- In this photo the set up for testing the free mass elements is shown.

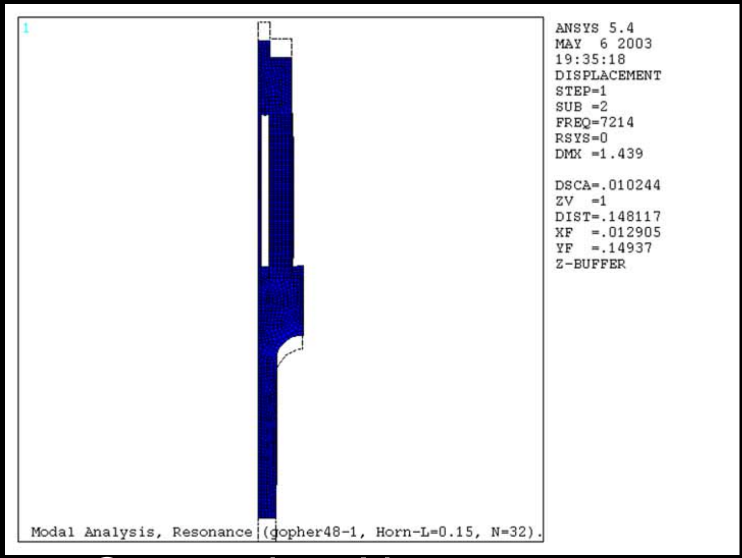
FEM analysis of the new horn

Purpose

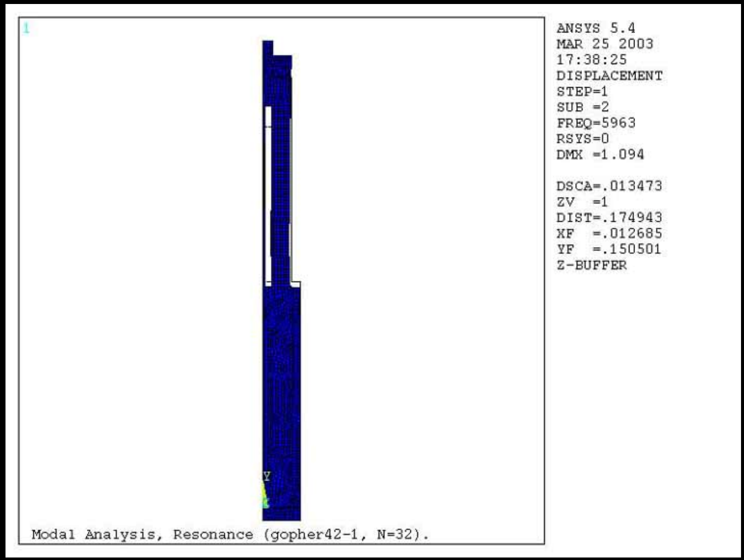


- Predict the resonance frequency
- Predict the electro-mechanical coupling factor
- Determine the neutral plan where both the displacement and velocity equals zero
- If the neutral plan does not fall at the designed position for fixture, modify the design parameters to make them coincident.
  - o Experience indicates that if the neutral plan and the position for fixture do not coincident, the fixture rapidly breaks
- Predict the horn tip displacement at a given damping ratio

Designs of the Gopher's actuator and the FEM results

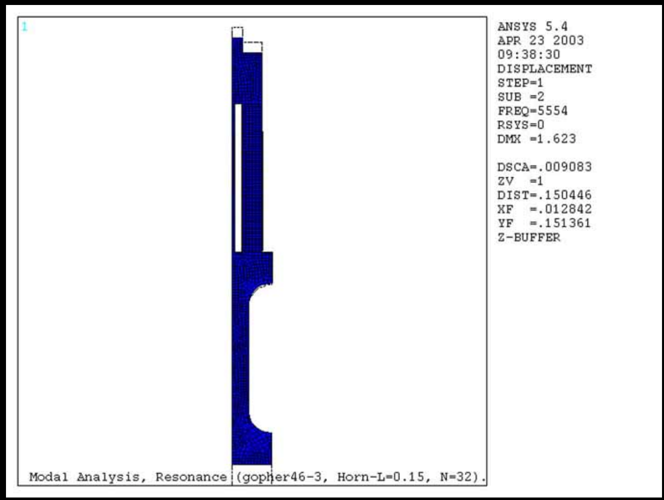


Conventional horn



Solid horn

- ANSYS was used for the analysis of the new horn
- 2-D axisymmetric elements were used
- In the Figure on the right the typical mesh is shown

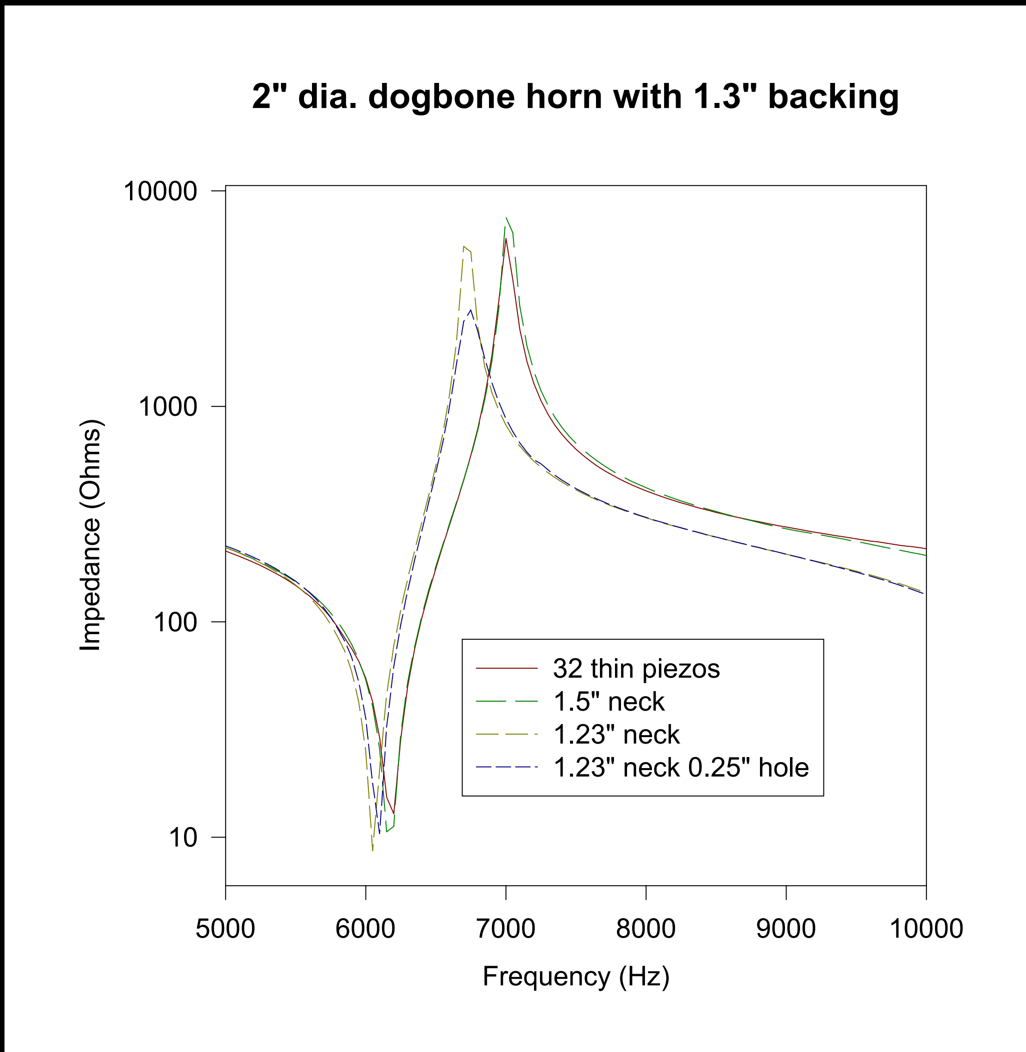


Dog-bone horn

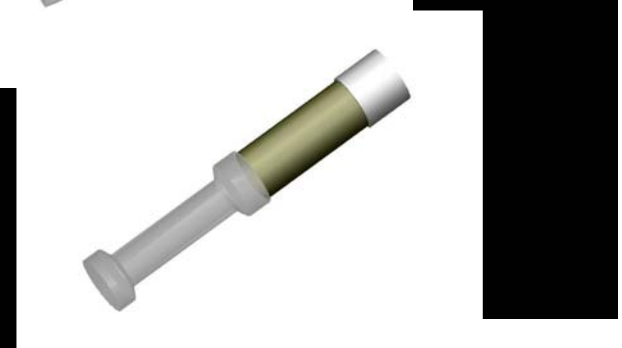
Modal Analysis

Reveals the Resonance Frequency, the Neutral Plan, and electro-mechanical coupling factor

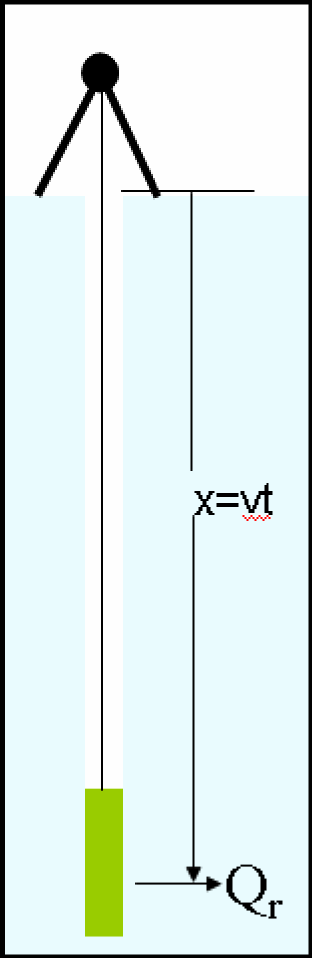
Dog-bone Horn Resonator



Design Evolution



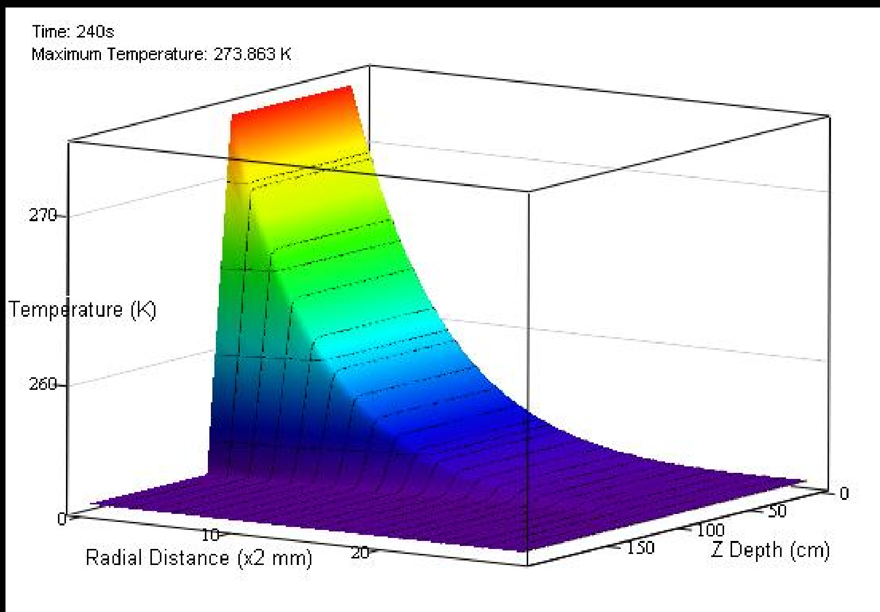
Thermal Modeling

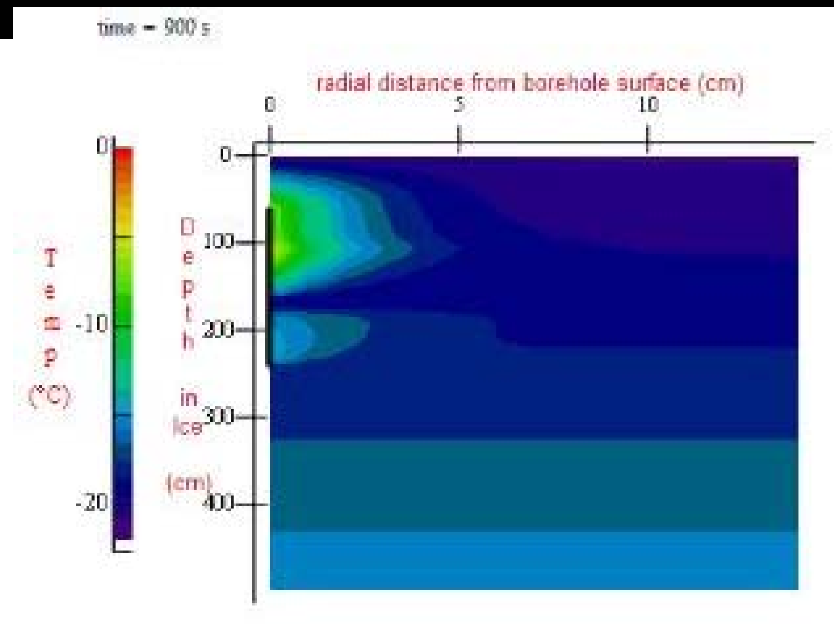


- While drilling, various parts of the Gopher release heat into the surrounding environment
- The ice surrounding the Gopher is approximately -20°C at the surface. To avoid refreezing onto bit the ice temperature should not exceed 0°C.
- A preliminary thermal model was developed to study the heat flow in ice.

- Calculations indicate that melting will occur near the piezoelectric stack.
- With an input of 50W, and approximately 10% released as heat at the bit/ice interface, the drilling rate is high enough that melting (and re-freezing) is not expected to occur around the bit.

Thermal Modeling (Initial approach)





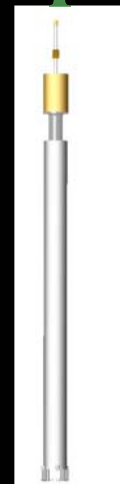
- Initial results suggest that melting may occur when device is driven at 50-100 W continuous level

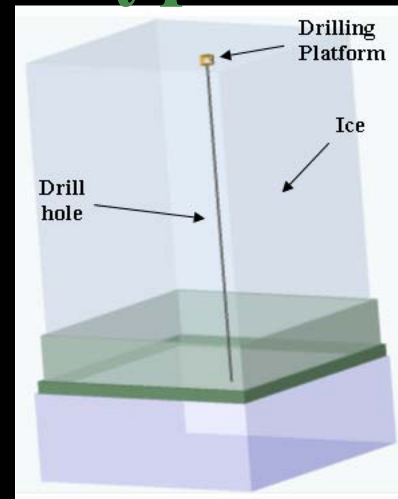
- Latent heat of melting will have to be included in model for the condition where the device is driven at higher powers

View of the U/C Gopher prototypes

Dog-bone horn

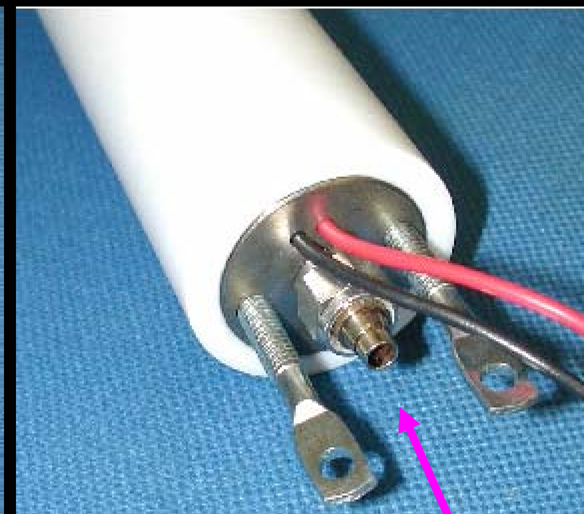
Straight horn



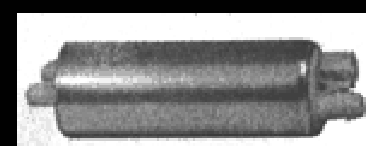


Current status

- Two prototype gopher breadboards were produced.
- The new driver is expected to be completed and delivered to JPL by 1/20/04
- A commercial pump was identified having outside diameter of 1-1/2" and overall length of 5-3/8".
- Samples of 1.5-m long -20°C ice are currently being made to test of the gopher.



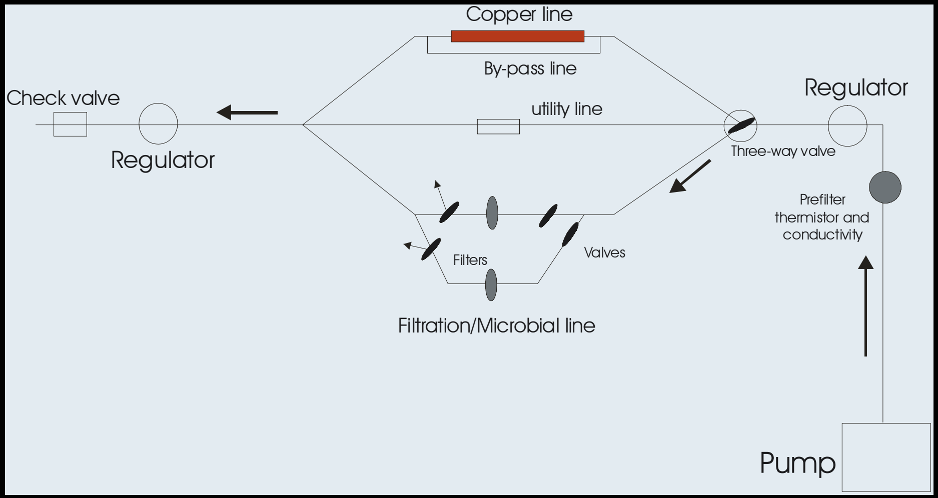
Swagelok to pump

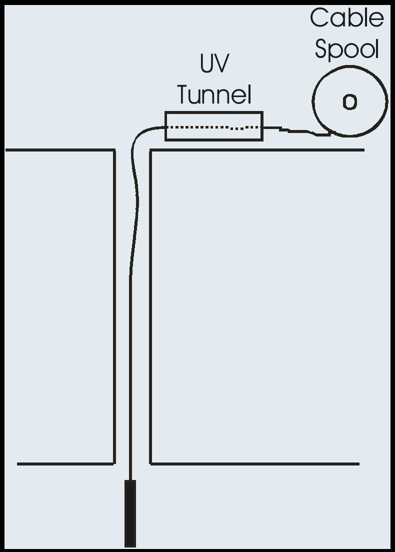


12 V DC pump

Sample Handling strategies

The gopher pump will send sample to the surface. Pressure in the tube will be regulated to prevent degassing. The sample line will be split at the surface for different sample requirements (e.g. microbial sampling, gas sampling, geochemistry sampling.





Cleanliness

Sample will be delivered to a “clean room” at the ice surface. Anything going down the hole will be alcohol cleaned and/or UV sterilized. At one point our protocol requires filling the borehole with DI water (to meet Antarctic environmental concerns). This water will be continuously filtered through a filter pump system. Standard clean room and microbial lab procedures will be used to insure we do not contaminate the lake and that our samples represent the community in the lake (if there)

Parameters to be Measured in Brine and sediments

Temperature, Salinity/conductivity, pH alkalinity

Gasses (don't want to see any atmospheric contamination);
- CH_4, O_2, N_2, Ar, CO_2, H_2S,
- N_2O, H_2, DMS
- He isotopes (Poreda), and noble gasses (Ne, Kr, Xe), Tritium, CFC's

Water chemistry
- Full ion chemistry, Nutrients, Metals (speciated, and elemental)
- DIC, DOC, DON, del^{13}C DIC, del^{13}C DOC

Particulate chemistry – biotic or abiotic – dead or alive (0.2 um retained)
- POC, PON, del^{13}C POC, del^{15}N PON
- Lipids
- Pigments (chlorophyll, bacteriochlorophyll, rhodopsins, carotenoids, and all the others)
- Nucleic acids
- Microscopy: SEM, TEM, Epifluorescence, Brightfield

Culturing: Anoxygenic and oxygenic – various salinities, Halophile media; methanogen media, SRB, Denitrifiers, - metal reducers (magnetos)

In situ Activity: Heterotrophic - thymidine, leucine, mixed AA's, glucose,
Chemoautotrophic – CO_2 fixation, sulfide oxidation, ammonia oxidation, metal oxidation, methane oxidation
Photoautotrophic– CO_2 fixation

Preparations for field season:

1. NSF is requiring that the gopher meet two milestones prior to deployment in Antarctica:

   a. Core through a 3 m ice column in JPL dewar

   b. Core in field realistic situation in CONUS (e.g. glacier)

2. NSF is building a high power, heavy weight “gopher rescue” device to swallow and retrieve gopher if it gets stuck

3. Preliminary logistics arrangements have been negotiated

4. Environmental Assessment is in preparation

5. Group is investigating issues of materials compatibility, contamination protocols, gopher disturbance of samples, needs for maintaining Antarctic environmental protocols, sediment core catchers, etc.